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Endoparasitic helminths of fishes in three Alpine lakes in France and Switzerland

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Endoparasitic helminths of fishes in three Alpine lakes in France and Switzerland. – A systematic survey of endoparasitic helminths of 9 species of fishes from three Alpine lakes, Annecy, Bourget (both France) and Geneva Lake (Switzerland and France), is presented. Eleven species of intestinal helminths (2 Digenea, 7 Cestoda, 1 Nematoda and 1 Acanthocephala) were found in 272 of 372 (i.e. 73%) fish species examined. The dominant parasites were pseudophyllidean tapeworms *Eubothrium crassum* (Bloch, 1779) and *E. salvelini* (Schrank, 1790) in lake trout (*Salmo trutta* m. *lacustris*) and Arctic char (*Salvelinus alpinus*) respectively, and the proteocephalidean *Proteocephalus longicollis* (Zeder, 1800) in whitefish (*Coregonus lavaretus*).

Key-words: Endohelminths – fishes – Alpine lakes – France – Switzerland.

INTRODUCTION

Little attention has been paid to studies on the parasite fauna of Alpine lakes despite their importance for fishery and sport fishing (GERDEAUX *et al.* 1995). This is also valid for three large lakes in the western part of the Alps, namely Annecy and Bourget lakes in France and Geneva Lake situated between Switzerland and France.

Up to now, only a few data on the helminths parasitizing fishes in these lakes have been published, with most records related to Geneva Lake. ZSCHOKKE (1884) reported several taxa of *Ichthyotaenia* (= *Proteocephalus*) from fishes in Geneva Lake but most are now considered invalid (see SCHOLZ & HANZELOVÁ 1998). JOYEUX & BAER (1936) listed several helminth species from this lake, including tapeworms *Cyathocephalus truncatus*, *Eubothrium crassum*, *E. salvelini*, *Triaenophorus crassus*, *Proteocephalus dubius* (= *P. percae*), *P. longicollis*, *P. fallax*, *P. neglectus*, *P. salmonisumblae* (three latter species synonymized with *P. longicollis* – SCHOLZ & HANZELOVÁ

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1998), and *P. torulosus*. DOBY & JARECKA (1964), JARECKA & DOBY (1965), and MORANDI & PONTON (1989) studied the biology of *Proteocephalus* tapeworms (most probably *P. longicollis*) in whitefish (*Coregonus lavaretus*) from Geneva Lake and in experimentally infected copepods.

However, except for a study by GERDEAUX *et al.* (1995), who reported the occurrence of the pseudophyllidean cestode *Eubothrium salvelini* in Arctic char (*Salvelinus alpinus*), almost no information exists about species composition and richness of the helminth fauna of fishes in Annecy and Bourget lakes.

During studies on the ecology of fishes in Annecy and Bourget lakes, heavy infections of salmonids, in particular of Arctic char with *E. salvelini*, were recorded since December 1992 (D. Gerdeaux – unpublished data; GERDEAUX *et al.* 1995). In order to provide more detailed information about helminth parasites, samples of fishes from the above mentioned lakes and Geneva Lake were taken between 1992 and 1998. In this paper, a survey of endoparasitic helminths found is presented.

MATERIALS AND METHODS

Samples were taken from three peri-alpine lakes in the western part of the Alps, namely Annecy Lake (Lac d´Annecy), Bourget Lake (Lac du Bourget; both Haute Savoie, France) and Geneva Lake (Lac Léman; Switzerland and France).

All lakes are of glacial origin and they have steep banks and a relatively flat bottom. Annecy Lake is an oligotrophic lake with a surface of 2,800 hectares and maximum depth 65 metres. It is highly productive in fish, with highest natural production of coregone (whitefish) and stocking production of Arctic char. Bourget Lake is an eutrophic lake with a surface of 4,500 hectares and maximum depth 145 m. It is rich mainly in perch (*Perca fluviatilis*), lake trout (*Salmo trutta* m. *lacustris*) and cyprinid fishes; sustained by stocking yields of whitefish and Arctic char are rather low. Geneva Lake is a mesotrophic lake situated between Switzerland and France; it has a

TABLE 1

Number of fish examined

Species	Annecy	Bourget	Geneva	Total
Esox lucius	2	4		**6**
Salmo trutta m. *lacustris*	8	4	4	**16**
Salvelinus alpinus	34	16	12	**62**
Coregonus lavaretus	40	14	21	**75**
Lota lota	18		4	**22**
Alburnus alburnus			1	**1**
Rutilus rutilus	10		40	**50**
Tinca tinca		3		**3**
Perca fluviatilis	48	4	76	**128**
Total	**160**	**45**	**158**	**363**

surface area of 58,000 hectares and its maximum depth reaches 310 m. The fish community is halfway between the two others; perch, salmonids and cyprinids are of equal importance (GERDEAUX 1990).

A total of 363 fishes of 9 species was examined in September 1997 and June 1998 (Table 1). Fish were caught by local fishermen using gill nets or by angling. Digestive tracts were removed, placed into boxes with ice, transported to the laboratory and examined the same or next day. The worms found were fixed by hot 4% formalin and nematodes by hot 4% solution of formalin and saline, identified and counted. Voucher specimens have been deposited in the helminthological collections of the Natural History Museums in Paris and Geneva; and at the Institute of Parasitology, České Budějovice. Some additional records from the collection (INVE) of the Natural History Museum of Geneva are included.

RESULTS

A total of 11 species of endoparasitic helminths was found: 2 species of trematodes (Digenea), 7 species of tapeworms (Cestoda), 1 nematode (Nematoda) and 1 spiny-headed worm (Acanthocephala).

DIGENEA

1. **Asymphylodora tincae** (Modeer, 1790)

Host: tench (*Tinca tinca*).

Site: intestine.

Locality: Bourget, June 1998 (infected 2 of 3 fish examined; intensity of infection 3-296).

Comments: This is a frequent parasite specific to tench, occurring in the Palearctic Region (BYKHOVSKAYA-PAVLOVSKAYA & KULAKOVA 1987). The life cycle of this trematode includes only one intermediate host, a lymnaeid snail, in which tailless cercariae (cercariaeum) develops. The fish acquire infection after consuming the snail harbouring cercariaea (NAŠINCOVÁ & SCHOLZ 1994).

2. **Bunodera luciopercae** (Müller, 1776)

Host: perch (*Perca fluviatilis*).

Site: intestine.

Locality: Annecy, September 1997, June 1998 (12/48; 41.8; 3-100).

Comments: *B. luciopercae* is a typical intestinal parasite of percid fishes in Europe and the ex-USSR, with perch representing the most suitable host (BYKHOVSKAYA-PAVLOVSKAYA & KULAKOVA 1987). In some regions, the parasite exhibits marked seasonal patterns in the occurrence and maturation (see CHUBB 1979 for review). The life cycle includes 2 intermediate hosts (YAMAGUTI 1975).

CESTODA

3. **Caryophyllaeus laticeps** (Pallas, 1781)

Host: roach (*Rutilus rutilus*).

Site: intestine.

Locality: Annecy, September 1997, (one of 10 fish examined infected with 1 juvenile cestode).

Comments: It seems that this tapeworm, which is rather common parasite of cyprinid fishes in Europe and Eurasia (DUBININA 1987), is quite rare in the lakes studied. In Geneva Lake, it was not present in any of 40 roach examined in June 1995 and September 1997. Oligochaetes (Tubificidae) serve as intermediate hosts of this parasite (SEKUTOWITCZ 1932).

4. **Eubothrium crassum** (Bloch, 1779)

Hosts: lake trout (*Salmo trutta* m. *lacustris*); perch as paratenic host.

Site: intestine.

Localities: lake trout: Annecy, September 1997, June 1998 (8/8; 47.8; 4-172; of these, 358 adult specimens and 24 juvenile ones); Bourget, September 1997, June 1998 (4/4; 59.8; 35-89; 239 adults and 48 juvenile tapeworms); perch: Annecy, September 1997, June 1998 (4/48; 1.5; 1-3 juvenile specimens); Bourget, September 1997 (1/4; more than 50 juveniles).

Comments: *E. crassum* is a common parasite of salmonoid fishes, widely distributed in the Holarctic with two biological races, one freshwater and one marine (KENNEDY 1978a,b). In Europe, *E. crassum* occurs from the Arctic part of Norway to southern France and Switzerland (VIK 1963; KENNEDY 1978b, 1996). JOYEUX & BAER (1936) reported *E. crassum* from trout in Geneva Lake. Trout (*Salmo trutta*) is considered to be preferred host of the cestode, with prevalence often reaching 70-100% (WOOTTEN 1972). In the present study, *E. crassum* has not been recorded in the lake trout from Geneva lake (four hosts examinated). However, this parasite is common in the lake trout as indicated by recent samples from the Geneva Museum collection: Chens, 16.01.1992, 24.04.1998; Genthod 22-23.01.1992; Prangins, 08.03.1992; Hermance, 31.03.1993; Tougues, 14.01.1996; Coppet, 18.01.1998. Prevalence: 8/9.

In Annecy and Bourget lakes adult tapeworms were found exclusively in lake trout, whereas juveniles with the beginning of segmentation occurred in trout and perch. On the basis of the presence of juvenile tapeworms in prey fish as perch, ruff (*Gymnocephalus cernuus*) or three-spined stickleback (*Gasterosteus aculeatus*), it was supposed that two intermediate hosts are involved in the life cycle of this cestode (ROSEN 1918; JOYEUX & BAER 1936; AKHMEROV 1962). However, field data (VIK 1963; WOOTTEN 1972; REIMER 1984) indicate that there is only one obligatory intermediate host, a copepod, and prey fish serve as paratenic hosts (KENNEDY 1978a,b). JOYEUX & BAER (1936) reported common occurrence of juvenile *Eubothrium* tapeworms from several fish species in Geneva Lake. Although these juvenile cestodes could not be identified, it can be assumed that they might belong to *E. crassum*.

5. **Eubothrium salvelini** Schrank, 1790

Host: Arctic char (*Salvelinus alpinus*).

Site: intestine.

Localities: Annecy, September 1997, June 1998 (34/34; 19.6; 1-60; 458 adult specimens and 209 juveniles); Bourget, September 1997, June 1998 (16/16; 19.4; 2-39; 283 adults and 27 juveniles).

Comments: *E. salvelini* is considered a specific parasite of Arctic char in Europe and Eurasia, with its distribution largely coincident with that of its host (KENNEDY 1978a,b). It is a fairly common parasite of Arctic char and it has been reported from this fish species in Switzerland and France (JOYEUX & BAER 1936; GERDEAUX *et al.* 1995), Austria (RYDLO 1970, 1985; KRITSCHER 1991), Germany (REIMER 1984; HOFFMANN *et al.* 1986a; ENGELHARDT & MIRLE 1993) as well as in northwestern Europe (NYBELIN 1922; WOOTTEN 1972; KENNEDY 1978a,b; KRISTOFFERSEN 1995; KNUDSEN *et al.* 1997). Similar to the present study, high prevalence (70-100%) and intensity of infection (up to 60 worms) were reported in other localities (SOBECKA & PIASECKI 1993), including Alpine lakes (REIMER 1984). In North America it occurs also in other salmonid fishes as *Oncorhynchus* (SMITH 1973; KENNEDY 1978a,b; BOYCE 1979; MUZZAL 1995).

It has been demonstrated experimentally (BOYCE 1974) that copepods serve as the only intermediate hosts. Field data suggest that the infection level and its variation among individual localities depend largely upon proportion of planktonic copepods in the food of Arctic char (REIMER 1984). In contrast to *E. crassum*, no juvenile tapeworms were found in other fish than Arctic char during the present study.

6. **Proteocephalus longicollis** (Zeder, 1800)

Host: whitefish (*Coregonus lavaretus*).

Site: intestine.

Localities: Annecy, September 1997, June 1998 (36/40; 113 adults and a great number of juvenile cestodes, with intensity of infection ranging from 17 to more than 1000 (precise number not counted); Bourget, September 1997, June 1998 (11/14; 7.8; 1-30; 60 adults and 26 juveniles); Geneva Lake, September 1997 (8/21; 14,9; 2-58; 36 adults and 233 juveniles).

Comments: It has been demonstrated that *P. longicollis* (syns. *P. exiguus*, *P. fallax* and *P. neglectus*) is the only *Proteocephalus* species occurring in salmonid and coregonid fishes in Europe (SCHOLZ & HANZELOVÁ 1998). It is a highly variable species occurrung in a wide range of fishes including brown, rainbow and brook trouts and whitefish (HANZELOVÁ *et al.* 1995, 1996; SCHOLZ & HANZELOVÁ 1998). In the lakes investigated, adult worms were found exclusively in the intestine of whitefish whereas Arctic char and lake trout were free of *P. longicollis* infection. However, a fry of Arctic char and lake trout from a hatchery on Annecy lake were heavily infected with *P. longicollis* (D. Gerdeaux - unpublished data). JOYEUX & BAER (1936) also reported *P. longicollis* from lake trout, Arctic char and whitefish in Geneva Lake. *Proteocephalus* tapeworms, most probably conspecific with *P. longicollis*, were found in whitefish from Geneva Lake by DOBY & JARECKA (1964), and MORANDI & PONTON (1989).

Intermediate hosts of *P. longicollis* are planktonic copepods (see SCHOLZ 1999 for review). In Geneva Lake, *Cyclops strenuus* and *C. abyssorum* have been reported as intermediate hosts of *Proteocephalus* sp. (most probably *P. longicollis*) by JARECKA & DOBY (1965). In Annecy lake, *Cyclops prealpinus* serves as dominant intermediate host of this parasite (V. Hanzelová - unpublished data).

A high number of metacestodes was found in whitefish in all three lakes. Much lower number of adult worms in these fish indicates that only a very small proportion of juvenile worms reaches maturity (about 0.5-1% estimated for *P. filicollis* – HOPKINS 1959).

7. **Proteocephalus percae** (Müller, 1780)

Hosts: perch (*Perca fluviatilis*); burbot (*Lota lota*) as alternative host.

Site: intestine.

Localities: perch: Annecy, September 1997, June 1998 (27/48; 6.4; 1-53); Bourget, September 1997, June 1998 (2/4; 4 and more than 100 juveniles); Geneva, June 1996 (20/76; 2.2; 1-14); burbot: Annecy, June 1998 (2/18; 2.5; 1-4).

Comments: *P. percae* is a common parasite of perch, reported also from other percid fish in the Palearctic (SCHOLZ & HANZELOVÁ 1998). In lakes under consideration, it occurs fairly frequently in perch. Burbot represents only an alternative, probably postcyclic host of *P. percae*. It is known that predatory fishes as pike, trout, eel or burbot may harbour *P. percae* tapeworms and serve as alternative (paradefinitive, postcyclic or accidental) hosts (SCHOLZ 1998). Life cycle of this cestode involves a copepod intermediate hosts (WOOTTEN 1974).

8. **Proteocephalus torulosus** (Batsch, 1786)

Host: bleak (*Alburnus alburnus*).

Site: intestine.

Locality: Geneva, June 1995 (1/1; 1).

Comments: This is a typical parasite of cypriniform fishes (Cyprinidae and Cobitidae), occurring in Europe, Asia and western part of North America (SCHOLZ & HANZELOVÁ 1998). It occurs preferably in riverine ecosystems rather than in lakes. Only one bleak was examined in this study and it is possible that *P. torulosus* occurs more frequently in the lakes studied. JOYEUX & BAER (1936) also reported bleak as the definitive host of this tapeworm from Geneva Lake. Intermediate hosts of *P. torulosus* are planktonic copepods, in particular *Cyclops* spp. (WAGNER 1917; SCHOLZ 1993).

9. **Triaenophorus nodulosus** (Pallas, 1781)

Hosts: pike (*Esox lucius*); perch as the second intermediate host.

Sites: intestine (adult tapeworm); liver (plerocercoids in perch).

Localities: pike: Annecy, June 1998 (1/2; 12); perch: Annecy, September 1997, June 1998 (20/48; 3.5; 1-10); Geneva, June 1995 (number not counted).

Comments: *T. nodulosus* is a specific parasite of pike in the Palearctic Region (KUPERMAN 1973). It frequently occurs in Alpine lakes in Austria and Germany (RYDLO

1985; HOFFMANN *et al.* 1986b). The life cycle of this cestode includes two intermediate hosts, a copepod in which a procercoid develops, and a fish where a plerocercoid is encysted in the liver. Infection level with adults and plerocercoids in fishes from the lakes studied is fairly low compared to other localities (see CHUBB 1982 for review).

NEMATODA

10. **Cammallanus lacustris** (Zoega, 1776)

Hosts: perch (*Perca fluviatilis*), burbot (*Lota lota*).

Site: intestine.

Localities: perch: Annecy, September 1997, June 1998 (36/48; 8.1; 1-44); Bourget, September 1997, June 1998 (4/4; 11.3; 4-21); Geneva, June 1995 (number not counted); burbot: Annecy, June 1998 (5/18; 3.2; 1-6).

Comments: *C. lacustris* is a quite common parasite of predatory fish as pike, perch or burbot, widely distributed in the Palearctic Region (MORAVEC 1994). In Annecy and Bourget lakes, perch is apparently the principal host of this nematode, which develops through planktonic copepods (MORAVEC 1994). The absence of nematodes in pike from the lakes concerned may be related to the low number of fish examined.

ACANTHOCEPHALA

11. **Acanthocephalus lucii** (Müller, 1780)

Hosts: perch (*Perca fluviatilis*), pike (*Esox lucius*), burbot (*Lota lota*).

Site: Intestine.

Localities: perch: Annecy, September 1997, June 1998 (31/48; 9.6; 1-65); Bourget, September 1997, June 1998 (3/4; 2.0; 1-4); Geneva, June 1995 (number not counted); pike: Annecy, June 1998 (1/2; 6); burbot: Annecy, June 1998 (5/18; 3.2; 1-6).

Comments: *A. lucii* is a very frequent parasite occurring in a wide spectrum of fishes of different families in the Palearctic Region (BAUER 1987). In the lakes studied, it forms an important part the helminth fauna of perch and occurs commonly also in burbot and pike. Intermediate host of *A. lucii* is the isopod *Asellus aquaticus* (KOMAROVA 1950).

DISCUSSION

A total of 11 species of endohelminths was found in fishes from the three Alpine lakes studied. The most characteristic feature of these helminth communities is a high number (7) of cestode species, which represents the dominant part of the helminth fauna in all localities. Prevalence of *E. salvelini*, *E. crassum* and *P. longicollis* in Arctic char, lake trout and whitefish, respectively, reached 90-100%, and intensity of infection was also considerably high. Common occurrence of *Eubothrium* tapeworms and *P. longicollis* have also been reported from other lakes in the Alps and from northern Europe (KENNEDY 1978a,b; REIMER 1984; BRISTOW & BERLAND 1991; KRISTOFFERSEN 1995).

Considering existing literature data on the helminth fauna of fishes from the lakes studied, it is worth of mention that two other tapeworms, reported by JOYEUX & BAER (1936) from Geneva Lake, have not been found in this study. Instead of *Triaenophorus crassus*, *T. nodulosus* has been found. It is possible that former species is rather rare in pike population. The absence of *Cyathocephalus truncatus*, in our samples, a parasite which was reported from trout, whitefish and burbot by JOYEUX & BAER (1936), is difficult to explain. Since these authors did not provide data on the infection rate, occurrence of *C. truncatus* in Geneva Lake cannot be excluded with certainty.

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